The structuring role of marine life in open ocean habitat: importance to internat...

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Introduction

Areas beyond national jurisdiction (ABNJ) cover 58% of the ocean surface and lie outside the 200 nautical mile limits of national sovereignty (exclusive economic zones). International concern has steadily increased over the multiplication and intensification of threats to marine biodiversity in ABNJ, fragmented and uncoordinated management, and the lack of a comprehensive legal framework to properly address threats (Ban et al., 2014 ; Merrie et al., 2014 ; Gjerde et al., 2016 ; Wright et al., 2016). Global agreements on environmental protection recognize steep biodiversity losses in ABNJ and have set targets to protect > 10% of coastal and marine areas in marine protected areas (MPAs) (Convention on Biological Diversity, 2010 ; United Nations, 2015). However, there is presently no agreed mechanism to protect biodiversity in ABNJ.

Following 10 years of informal negotiations, in March 2016 delegates from 193 countries, and representatives from numerous intergovernmental and non-governmental organizations, met at the United Nations (UN) in New York for the first of four meetings to negotiate the elements of an " international legally binding instrument" (ILBI) for the conservation and sustainable use of biodiversity beyond national jurisdiction under the UN Convention on the Law of the Sea (UNCLOS). These negotiations are framed by four issues which delegates have agreed must be considered " together and as a whole": (1) marine genetic resources, including benefit sharing; (2) area-based management tools, including MPAs; (3) environmental impact assessments; and (4) capacity building and the transfer of marine technology (UNGA, 2015 ; Gjerde et al., 2016 ; Wright et al., 2016) This process should result in recommendations to the UN General Assembly by the end of 2017.

If successful, these negotiations will lead to an intergovernmental negotiating conference in 2018 to improve governance and management of biodiversity beyond national jurisdiction. However, while the ILBI will, hopefully, facilitate conservation and sustainable use of biodiversity in ABNJ, including a mechanism for establishing MPAs, these discussions highlight a further problem: namely, defining what to protect.

Existing global targets measure progress toward biodiversity conservation using the extent of ecosystems and habitats covered by protected areas (Convention on Biological Diversity, 2010). However, while we have a good working framework for terrestrial and coastal habitats, habitats in ABNJ, and particularly the open ocean, are less understood and poorly defined (e. g., IUCN, 2017). To inform these discussions we consider what constitutes " habitat" in the largely fluid environment of the open ocean.

Relating Habitat Concepts to Areas Beyond National Jurisdiction

Habitat or ecosystem concepts overlap substantially. The Convention on Biological Diversity (CBD) (Article 2) defines " ecosystem" as " a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit," and " habitat" as " the place or type of site where an organism or population naturally occurs" (Convention on Biological Diversity, 2010). The definitions are therefore interrelated, and application of the terms is scale-dependent.

Even without clear definitions, the idea that the world is divided into a series of ecosystems and habitats is most easily grasped when fixed entities comprise a habitat with discrete boundaries (although visible boundaries often conceal complex networks of wider connections that may be overlooked–Box 1). For instance, on land it is easy to conceive where a lake or forest end and a different habitat or ecosystem begins. This principle clearly translates to coastal systems where, for example, mangrove trees, seagrass meadows, or coral and oyster reefs act as easily defined structuring elements. Similarly, some habitats in ABNJ, especially seabed features such as seamounts, hydrothermal vents, and ocean ridges, offer defined features around which boundaries can be drawn using traditional principles.

Box 1. Considering complex connections amongst ecosystems in the MPA context.

Whether on land or in the sea, ecosystems are an interconnected continuum in space and time across living and non-living realms. While ecosystems on land may be easier to perceive and define as distinct entities, it is increasingly understood that successful management and conservation must incorporate connectivity with the surrounding environment. For example, migratory salmon are an important mediator of marine-derived nutrients to freshwater and riparian habitats and the animals that rely on them; without considering the underlying ecology and importance of salmon in these systems, management is unlikely to achieve desired outcomes of maintaining habitat diversity, structure and function (Darimont et al., 2010 ; Artelle et al., 2016). Similarly, anthropogenic nutrient inputs from land may result in eutrophication of freshwater, estuarine, and coastal ecosystems leading to dead zones (Diaz and Rosenberg, 2008), harmful algal blooms (Heisler et al., 2008), contaminated water and seafood (Heisler et al., 2008), and increased mortality of wildlife (Fey et al., 2015). Broader considerations than simply the apparent spatial footprint of a habitat are therefore needed to attain management and conservation objectives.

The same broad approach applies to management in ABNJ. A seamount or hydrothermal vent ecosystem, for example, is not just a reflection of the bathymetric feature but rather a combination of influences which includes the water column and the creatures on and within it (Clark et al., 2010 ; Levin et al., 2016). Nutrient and food subsidies from seeps and vents influence surrounding fish and fisheries (Grupe et al., 2015) in a similar manner to coastal habitats such as seagrass meadows (Heck et al., 2008), although quantification is still limited. Other seabed features likely exert similar influences (Morato et al., 2010 ; Letessier et al., 2016). The vertical and horizontal footprint of such ecosystems is therefore much larger than simply where the physical habitat manifests, with the extent and scales of influence varying from place to place and among ecosystems (e. g., Levin et al., 2016). At the sea surface, distinctive habitats based on oceanographic features and areas of high productivity and biodiversity are identifiable using sea surface temperature, temperature at depth, chlorophyll, and nitrates among other variables (e. g., Hobday et al., 2011). Beneath these areas often lie diverse seabed ecosystems (Woolley et al., 2016) with nutrients, dissolved organic matter, and minerals moved through the water column, mediated by marine life as well as topographically induced currents, which influence both seabed and water column habitat characteristics (Turner, 2015 ; Soetaert et al., 2016).

For an international legally binding instrument for biodiversity protection beyond national jurisdiction under the UN Convention on the Law of the Sea to be effective, it needs to ensure these broader considerations are incorporated. To achieve this, species and habitat conservation need to be integrated, recognizing that habitats will not be protected if their component species are not.

Fluid realms, such as the open ocean (Norse, 2005) and airspace (Diehl, 2013), challenge our conception and application of habitat and ecosystem ideas. Predictable, broad oceanographic features, such as frontal zones, which aggregate nutrients and food and attract predators, offer opportunities to delineate boundaries (Scales et al., 2014). But what exactly defines the habitat? Is it the water, or the species that live there? With the exception of floating *Sargassum* weed (Hemphill, 2005), there is little structure-forming biomass in pelagic systems and even this is not fixed in space. The biomass present is held in the bodies of the creatures that live in the water and is highly mobile. It is those creatures, and the ecological roles they fulfill, we argue, that constitute " habitat" in the open sea.

Habitats as a Function of Their Inhabitants

Living and non-living realms interact to characterize ecosystems. The occupants of any habitat create and alter the system they live within. Species that create more complex habitat by modulating the availability of resources to other species are known as " ecosystem engineers" (Jones et al., 1994). Most research identifying marine organisms as ecosystem engineers has focused on species that either attach or interact with seabed communities, such as corals, bivalves, seagrasses, and species that modify sediments (e. g., Soetaert et al., 2016). Only recently have some begun to explore the potential for other marine organisms to act as ecosystem engineers. Examples in the open ocean include phytoplankton and zooplankton (Jones et al., 1994 ; Breitburg et al., 2010), and baleen and sperm whales (Roman et al., 2014).

The structuring role of plankton in pelagic food-webs has long been recognized. They are critical to ecosystem function, and their abundance and biomass determines the distribution and productivity of marine life (Chassot et al., 2010 ; Watson et al., 2015). However, plankton may also be considered ecosystem engineers—affecting the photic, chemical and thermal regimes of water and consequently the suitability of that habitat for other life (Haury et al., 1978 ; Duffy and Stachowicz, 2006 ; Breitburg et al., 2010). For example, Antarctic krill (*Euphausia superba*) are a fundamental food source for predators from squid to baleen whales (Constable et al., 2000), play a major role in ocean productivity by recycling iron in surface waters (Nicol et al., 2010), alter organic matter and trace element concentrations in surface waters during molting (Nicol and Stolp, 1989), and may be an important carbon sink (Swadling, 2006 ; Tarling and Johnson, 2006). However, most research examines krill-based food-webs or environmental factors affecting their populations rather than their influence on the non-living realm. Advances in technology and increased demand are anticipated to expand zooplankton fisheries in the future leading to calls for precautionary management to avert adverse ecosystem and habitat consequences of exploitation (Nicol et al., 2012 ; Brotz, 2016 ; Kawaguchi and Melle, 2016).

Emerging evidence suggests that mobile marine species can transform the environment as they move through it, transferring nutrients within the water column (deep to shallow and vice versa) and across oceans (Wilson et al., 2009 ; Pershing et al., 2010 ; Roman and McCarthy, 2010 ; Roman et al., 2014 ; St John et al., 2016). For example, depletion of whales due to commercial whaling resulted in substantial deep-sea habitat loss through a reduction in dead whale " falls" (Smith, 2007), declines in primary productivity due to reduced nutrient shuttling (Nicol et al., 2010 ; Roman and McCarthy, 2010), changes in food-web structure and biogeochemical cycles (Lavery et al., 2010 ; Roman and McCarthy, 2010), and reduced potential for organic carbon sequestration (Lavery et al., 2010 ; Pershing et al., 2010). The consequences of extraction therefore extended far beyond the decline of individual whale species.

Similar ecosystem-wide changes can be expected from exploitation of other large-bodied or highly abundant marine animals. For instance, mesopelagic fish (200–1, 000 m) undertake daily migrations between near-surface and deep water (Robinson et al., 2010). Estimates suggest the global biomass of mesopelagic fish is on the order of 10 billion tones and, while there is uncertainty in this number, they likely represent the most abundant vertebrates on Earth (Irigoien et al., 2014) and the largest structuring biomass in the open sea. Their mass migration provides critical links in biogeochemical cycles across the water column, promoting carbon uptake and storage, thereby affecting climate regulation (Robinson et al., 2010 ; Giering et al., 2014 ; St John et al., 2016), modifies fluxes of nutrients and oxygen (Robinson et al., 2010 ; Bianchi et al., 2013a , b), and helps sustain the metabolic requirements of mesopelagic ecosystems (Burd et al., 2010 ; Bianchi et al., 2013b). They are also a key resource for higher trophic levels such as tunas and billfish (Potier et al., 2007 ; Duffy et al., 2017). There is increasing interest in exploiting mesopelagic fish, particularly for fishmeal and oil, but technical and economic constraints still prevent large-scale commercial activity (St John et al., 2016). Nonetheless, licenses to fish mesopelagics have been issued by Norway and Pakistan (The Economist, 2017), although the US has proactively prohibited directed commercial fisheries in its Pacific Ocean due to concerns over potential adverse ecosystem consequences (NOAA, 2016).

Many exploited marine species such as billfish, tuna, sharks, and rays that spend time in ABNJ regularly undertake extensive horizontal movements and deep-dives into the meso- and even bathypelagic (1, 000–4, 000 m) realms (Thorrold et al., 2014 ; Abascal et al., 2015 ; Fuller et al., 2015 ; Howey et al., 2016). Their roles in biogeochemical cycles are largely unquantified, but the movements link surface waters and the deep ocean and are likely to influence habitat characteristics in a similar manner to whales and mesopelagic fish.

Mobile, open ocean predators also structure habitats through their physical presence and behaviors. For example, hunting pelagic fish such as tuna provide visual cues to seabirds enabling prey detection over greater distances and enhancing bird foraging success by forcing prey close to the surface (Maxwell and Morgan, 2013). Other marine organisms may control the abundance of prey or act as food, either directly or through detritus, influences that change across life stages (Young et al., 2015). Although rarely considered this way, these roles are analogous in their significance to the structuring influence of kelp or seagrass in coastal habitats.

There are many examples of altered ocean food-web dynamics following depletion of apex predators. For example, the recent range expansion of the Humboldt squid into the eastern North Pacific has been linked to reduced predation and competition with large predatory fish targeted by fisheries, and expanded low oxygen waters (Zeidberg and Robison, 2007). Predator depletion has well-known effects on coastal habitats, e. g., sea otter loss led to kelp decline due to reduced predation on herbivores (Estes et al., 2011), and overfishing of apex predators has altered trophic structure leading to increased abundance of mid-size predators (Heithaus et al., 2008 ; Ritchie and Johnson, 2009 ; Ferretti et al., 2010 ; Ortuño Crespo and Dunn, 2017). In the open ocean, where ecosystems are defined by their inhabitants, community level impacts equate to ecosystem impacts. While the ecological impacts of apex predator depletion in ABNJ are poorly understood, by inference from known cases they can be expected to be significant.

Unifying Habitat and Species Protection in Areas Beyond National Jurisdiction

A habitat is malleable—preserving it in a particular state requires protection of the things that make it distinctive and recognizable. A woodland will not remain a woodland without protection for trees. It is easy to understand this because we can see the difference cutting down trees makes. However, protecting trees does not produce the same forest as protecting trees and all the species that live in and around them (Brodie, 2016), although the assumption is often made that it does. Similarly, protecting a seafloor habitat without protecting the species that regulate it, such as parrotfish in coral reefs (Mumby, 2009) or spiny lobster in kelp forests (Halpern et al., 2006), will alter the functioning and resilience of that habitat if those species are depleted. In the open ocean it is much harder to understand that removing big, predatory or highly abundant fish or marine mammals transforms an open sea habitat because it looks much the same as before. But the nature of open water habitats is also dictated by what occupies the space.

Nature conservation often operates on two levels, habitat and species protection, with protection added in layers through different laws and in varying mixes. Such an approach can create perverse outcomes, however, when the inanimate is emphasized at the expense of the animate. For example, it is unclear to many, including nature conservation bodies, what protecting shallow, sub-tidal sandbanks under the EU Habitats Directive should entail. Does it mean ensuring the sand remains where it is, or is there some obligation to protect the animals and plants that live on or around sandbanks? Most people would assume the latter, yet in many cases, there is no protection given to Special Areas of Conservation from highly disturbing and destructive practices like bottom trawling and dredging (Plumeridge and Roberts, 2017). It is the sand, not wildlife, that prevails under this stewardship. The physical characteristics of an area act only as a placeholder for the life that could or does occupy it. Areas little affected by human activity will possess the most intact communities (D'agata et al., 2016), others will need to rebuild their wildlife under protection. The habitat that results from protection therefore depends on the level of protection given and even the most diligent network design schemes will fail if the sites chosen get little protection. Strongly and fully protected MPAs (Lubchenco and Grorud-Colvert, 2015) therefore promote the highest levels of complexity and the most intact ecosystems (Edgar et al., 2014).

Conclusions and Suggestions

Given the horizontal and vertical spread of human activities through ABNJ (Merrie et al., 2014), the structure and function of open ocean habitats has certainly altered over time (Ortuño Crespo and Dunn, 2017). While some land-based habitats retain high conservation value as a function of human use, e. g., highly diverse flower meadows from seasonal cutting and grazing regimes, or understory flowers, insects and birds from coppiced woodlands, we are not aware of any comparable examples in the sea. Evidence that mobile species benefit from spatial protection in national waters is increasing (Jensen et al., 2010 ; Edgar et al., 2014 ; Dunphy-Daly, 2015). Likewise, protection could offer benefits to such species in ABNJ but the extensive movements of many of the animals inhabiting these regions reinforce the need for strong complementary protection measures to be applied outside MPA boundaries. Such measures could include dynamic management, effective fisheries regulation and, increasingly, precautionary regulation of emerging activities (Dunn et al., 2011 , 2016 ; Maxwell et al., 2015 ; Jaeckel et al., 2017).

On purely biological grounds, the case is clear for fish and other exploited species to be an integral part of any agreement to protect biodiversity in ABNJ. Current negotiations consider what marine life and activities should be covered by any new protective legislation, and whether MPAs should be established through a new overarching mechanism or through existing regional and sectoral frameworks. The argument frequently made is that fisheries management bodies have a legal remit and competence to manage fisheries and are therefore best placed to look after fish (Vincent et al., 2014). But these bodies have so far failed to safeguard fisheries or fish (Gilman et al., 2014), are often limited to certain species, do not comprehensively cover the oceans, and introduce measures only applicable to members (Vincent et al., 2014). Furthermore, other activities in ABNJ affect marine life (e. g., Ramirez-Llodra et al., 2011) over which fisheries bodies have no remit. Objectives of MPAs go beyond tackling fishery problems, addressing threats from other activities such as maritime traffic or oil, mineral and genetic resource exploration and exploitation, as well as protecting biodiversity and ecosystem structure and function, and supporting cultural values and ecosystem services.

Given the indivisibility between species and habitats, and the potential for cumulative impacts from human activities currently managed separately, protection of biodiversity in ABNJ will require comprehensive and strategic management across sectors. Moving from a regional to global approach would also: promote universal participation; allow comprehensive environmental impact assessments to established standards that address cumulative impacts from different activities; provide a mandate to implement ecologically representative MPA networks; and help harmonize the implementation of UNCLOS with the CBD, Sustainable Development Goals, the Paris Agreement, and other instruments. Furthermore, the interrelatedness of the four issues framing the ABNJ ILBI negotiations cannot be addressed in isolation from each other. For example, environmental impact assessments will promote informed decisions regarding acceptable levels of harm from activities on marine life which represent genetic and provisioning resources, prior to activities being undertaken. While negotiations are constrained by the requirement that any new agreement " should not undermine existing relevant legal instruments and frameworks and relevant global, regional and sectoral bodies" (UNGA, 2015), the opportunity is there to unify existing regulatory and governance mechanisms and fill gaps where they exist.

Protection of animal life is crucial in the open ocean, because they structure the habitats there. Therefore, targets for habitat protection beyond national jurisdiction can only be fully met by protecting animal and plant communities in their entirety. Globally, efforts to align habitats and species conservation have increased in recent years. For example, 66 Ecologically and Biologically Significant Areas have been defined under the CBD that cover places in ABNJ (Bax et al., 2016) and the IUCN is developing a Red List for Ecosystems which includes marine habitats (Keith et al., 2015). Other efforts are pioneering approaches to identify important areas based on species distributions (e. g., Key Biodiversity Areas, Edgar et al., 2008 ; Important Marine Mammal Areas, Corrigan et al., 2014). These efforts are designed to inform global policy and future decisions regarding protection. Achieving habitat representation under global conservation targets will involve selecting sites for protection identified through these and similar efforts. Habitat conservation in whichever places are chosen for protection, however, will only be successful if MPAs and other measures safeguard more than just water, offering real refuges and protection for the creatures that define open sea habitats.

The ongoing UN negotiations for the conservation and sustainable use of biodiversity beyond national jurisdiction present a unique opportunity to move from a sectoral and fragmented ABNJ management system to one that is holistic and based on the ecosystem approach. To be effective the ILBI should consider habitats a function of their inhabitants and represent all marine life within its scope. To do otherwise will fail to improve governance and management of ABNJ and undermine our ability to recover depleted species and repair degraded habitats.

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All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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Conflict of Interest Statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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